

LASER POINTER BASED INTERACTIVE DISPLAY SYSTEM AND METHOD THEREOF

Field of the Invention

[0001] The present invention relates to a user interactive computer controlled display system. More particularly, it relates to a system that employs a laser pointer based interface to control the display of computer-generated images.

Background of the Invention

[0002] Large displays are increasingly popular for everyday use, at work or at home. Computer generated images are commonly presented to a large audience by optically projecting these images onto a projection screen. Interacting with these displays requires different form of control than for a classical desktop computer. Available means include touch sensitive panel, light/electronic pens, laser pointers or other wireless handheld input devices, as well as advanced speech and gesture recognition systems. Given the low reliability of gesture and speech recognition system and the relatively high price of large touch displays, a lot of research is currently focusing on laser pointer based interaction system.

[0003] In respect of a typical laser-pointer based interactive display system, a laser pointer is used to generate a laser spot onto the projected image displayed on the projection screen. The laser spot is detected by a video camera; and the acquired information including the coordinate of the laser spot, is transmitted to the computer, thereby controlling the display of the computed generated images.

[0004] The performance of the laser-pointer based interactive display system depends on reliability of laser spot detection. A reliable laser spot detection method/system should be able to identify the laser spot on projected images of different colours and shades, and to differentiate the instructing laser spot from the laser spot flying over the projected image by accident. The most commonly used detection method is based on the brightness of the laser spot. When any image element has a brightness exceeding a predetermined threshold, it will be identified as a laser spot. However, along with usage, the brightness of the laser spot will decrease, resulting in the variation in the performance

of the whole interactive display system. And it does not satisfy the required reliability of laser spot detection.

[0005] Hence, there is a clear need for an improved process/system for detecting laser spot and interactively controlling the display of computer-generated images.

Summary of the Invention

[0006] The present invention provides a laser-pointer based interactive display system and a process executable by the system for reliable detection of laser spot on the display surface so as to perform effective interactive control.

[0007] According to one aspect of the present invention, there is provided a process for detecting a laser spot superimposed on a display surface, the process comprises the steps of acquiring a reference image by an image sensing device, wherein the reference image is an initial acquired image of the display surface without the laser spot superimposed thereon; acquiring a target image by the image sensing device, wherein the target image is a successive acquired image of the display surface, for detecting the laser spot superimposed thereon; receiving the image data of the reference and target image by a processor from the image sensing device; identifying a region of change in the target image with respect to the reference image; if the region of change is identified, identifying a sub region in the region of change, where the dominant color is the color of the laser spot; calculating an aspect ratio of the sub region; and if the calculated aspect ratio falls within a pre-determined range, signaling that the laser spot is detected on the display surface in a region corresponding to the sub region in the target image.

[0008] In one embodiment of the process, the step of identifying a region of change in the target image further comprises the sub steps of dividing the reference image into a plurality of regions according to a pre-determined pattern; dividing the target image into a plurality of corresponding regions according to the same pre-determined pattern; calculating a correlation score in each region according to a change detection algorithm; and if any calculated correlation score is below a pre-set threshold, signaling that a region of change is identified in the corresponding region.

[0009] In one embodiment of the step of identifying a region of change in the target image, the change detection algorithm is performed according to the formula:

$$NCC(I_1, I_2) = \frac{\sum_i ((a_i - \bar{a})(b_i - \bar{b}))}{\sqrt{\sum_i (a_i - \bar{a})^2 \sum_i (b_i - \bar{b})^2}}$$

where I_1 is a region in the reference image; I_2 is the corresponding region in the target image, a_i is the image pixel intensity value for location i in I_1 ; b_i is the image pixel intensity value for location i in I_2 ; $\bar{a}$ is the average image intensity value for I_1 , and $\bar{b}$ is the average image intensity value for I_2 .

[0010] In another embodiment of the step of identifying a region of change in the target image, when a laser spot is detected in a region with respect to a target image, the region is recorded and a nearest neighbor rule is applied to the step with respect to the subsequent target image, according to which calculation of the correlation score starts from the regions nearest to the recorded region and then towards the further regions.

[0011] In another embodiment of the process, the step of identifying the sub region where the dominant color is the color of the laser spot, comprises the sub steps of calculating a dominant color ratio for each location in the region of change with respect to the color of the laser spot; selecting the location the calculated dominant color ratio of which exceeds a pre-determined threshold; and forming the sub region defined by the selected location.

[0012] In one embodiment, when the image acquired by the image sensing device is in RGB format and the color of the laser spot is selected from the group of red, green and blue, the dominant color ratio is calculated according to the formula

$$\text{Dominant color ratio} = L_i / (R_i + G_i + B_i)$$

wherein R_i is the value for the red component of the color image pixel in location i , G_i is the value for the green component of the color image pixel in location i , B_i is the value for the blue component of the color image pixel in location i , and L_i is the value for the color component constituting the color of the laser spot in location .

[0013] In another embodiment, the dominant color ratio is calculated according to the formula

$$\text{Dominant color ratio} = L_i / \text{SQRT}(R_i * R_i + B_i * B_i + G_i * G_i)$$

wherein R_i is the value for the red component of the color image pixel in location i , G_i is the value for the green component of the color image pixel in location i , B_i is the value for

the blue component of the color image pixel in location i , and L_i is the value for the color component constituting the color of the laser spot in location i .

[0014] According to another aspect of the invention, there is provided an interactive display system together with a process executable by the system for controlling image display. The system comprises a processor for generating an image and controlling the display thereof pursuant to an interactive signal; a display surface; a projector for projecting the processor-generated image onto the display surface; a laser pointer for generating the interactive signal by superimposing a laser spot on the display surface that has the projected image displayed thereon; and an image sensing device for continuously acquiring images of the display surface so as to detect the interactive signal. The process comprises the steps of detecting a laser spot superimposed on the display surface with respect to a projected image; calculating the duration of the detected laser spot; if the calculated duration exceeds a pre-set threshold, locating the position of the detected laser spot; if the position of the detected laser spot is within a pre-determined command region, executing a corresponding control action.

[0015] In one embodiment, the view size of the acquired image by the image sensing device is larger than that of the corresponding projected image on the display surface. The command region can be pre-defined within the projected image or in a boundary region of the projected image.

[0016] In another embodiment, a virtual button is created by the processor in the electronic image in a region corresponding to the pre-determined command region. The virtual button is in a color contract to the color of the laser spot.

[0017] In yet another embodiment, when a laser spot is initially detected in target image n , and consistently detected in the subsequent target image $n+i$ ($i=1,2,\dots$), the duration of the detected laser spot is calculated according to

[0018]
$$\text{Duration}(i) = T_{n+i} - T_n;$$

[0019] wherein T_n is the time when target image n is acquired by the image sensing device, and T_{n+i} is the time when target image $n+i$ is acquired.

[0020] In a still further embodiment, the corresponding control action is to display a previous/next processor-generated image, or to enter information to the processor-generated image, such as drawing a line.

[0021] The objectives and advantages of the present invention will become apparent from the following detailed description of embodiments thereof in connection with the accompanying drawings.

Brief Description of the Drawings

[0022] Preferred embodiments according to the present invention will now be described with reference to the Figures accompanied herein, in which like reference numerals denote like elements.

[0023] FIG. 1 illustrates a schematic diagram of an interactive display system in accordance with one embodiment of the present invention.

[0024] FIG. 2 illustrates a flow chart of a process executable by a computer for real-time display control, in accordance with one embodiment of the present invention.

[0025] FIG. 3 illustrates a flow chart of the steps for detecting laser spot in accordance with one embodiment of the present invention.

[0026] FIG. 4 illustrates the sub step of verifying the existence of the laser spot by aspect ratio calculation.

[0027] FIG. 5 illustrates the nearest neighbor rule applicable to the change detection sub step in accordance with one embodiment of the present invention.

[0028] FIG. 6 illustrates an example of applying the interactive display system and process to page up or down during an electronic slide show.

[0029] FIG. 7 illustrates an example of applying interactive display system and process to enter the draw mode in order to highlight the information on an electronic slide show.

Detailed Description of the Invention

[0030] The present invention may be understood more readily by reference to the following detailed description of certain embodiments of the invention.

[0031] Now referring to FIG. 1, there is provided a schematic diagram of an interactive display system in accordance with one embodiment of the present invention. The system 1 comprises a computer 2 for generating images and controlling image display pursuant to an interactive signal, a projection screen 3, a projector 4 for projecting the

computer generated images onto the projection screen 3, a laser pointer 5 for superimposing a laser spot 52 on the projected image to provide the interactive signal, and a camera 6 for continuously acquiring images on the projection screen 3 and communicating the acquired image data to the computer so as to detect the interactive signal.

[0032] In operation, the computer 2 generates and stores a series of electronic images 22 (not shown in FIG. 1) for display, each of which is transmitted to the projector 4 and projected onto the projection screen 3 as a corresponding projected image 42 (not shown in FIG. 1). The computer 2 controls the image display sequence and timing, pursuant to the interactive signal provided by a system operator 10. The operator 10 uses the laser pointer 5 to generate a laser spot 52 on the projected image, wherein the interactive signal is embodied in the presence, location and duration of the laser spot 52 on the projection screen 3 in relation to the projected image 42.

[0033] The camera 6 is directed at the projection screen 3 for continuously acquiring the image thereon at a pre-set sampling rate. Each acquired images 62 is subsequently transmitted to the computer 2 and analyzed for real-time display control. When the projected image 42 remains the same, the corresponding acquired images 62 are essentially identical to one another except for the presence of the laser spot 52 between successive acquired images 62. Once a laser spot 52 is detected and verified as an interactive signal, a pre-programmed corresponding control action is executed by the computer 2.

[0034] In one embodiment, the pre-set sampling rate of the camera 6 is preferably twenty five frames per second.

[0035] In one embodiment, the view size of the acquired image 62 is the same as that of the projected image 42. In another embodiment as shown in FIG. 6, the view size of the acquired image 62 is larger than that of the projected image 42, wherein boundary regions of the projected image 42 on the projection screen 3, such as 62a and 62b, are included.

[0036] In one embodiment, the corresponding control action is page up/down. In another embodiment, the corresponding control action is mode change, for example, the change to draw mode.

[0037] Now referring to FIG. 2, there is provided a flow chart of a process executable by the computer 2 for real-time display control based on the acquired images received from the camera 6, in accordance with another embodiment of the present invention. The process 100 comprises the step 200 of obtaining image data from the camera, step 300 of detecting laser spot therein, step 400 of determining the duration of the laser spot detected, step 500 of locating the detected laser spot, and step 600 of executing the corresponding control action. The details of each step will be discussed hereinafter.

[0038] In respect of a current projected image 42 (not shown in FIG. 2 but in FIG. 6), the process 100 starts with the step 200 of obtaining the image data of a reference image 64 (not shown in FIG. 2) and a target image 66 (not shown in FIG. 2). The reference image 64 is defined as the first acquired image 62 with respect to the current projected image 42, which is captured by the camera 6 at T_0 . The target image 66 is defined as any one of the successive acquired images 62 with respect to the same projected image 42.

[0039] Now referring to FIG. 3, there is provided a flow chart of the step 300 of detecting laser spot in accordance with one embodiment of the present invention. The step 300 comprises three sub steps, namely change detection 320, dominant color ratio calculation 340 and aspect ratio calculation 360.

[0040] The sub step 320 is to feature the change in the target image 66 (not shown in FIG. 3) with respect to the reference image 64 (not shown in FIG. 3). Prior to the analysis, all the acquired images 62, including the reference image 64 and the target image 66 are divided into a plurality of regions according to a pre-determined grid pattern.

[0041] In one embodiment, each region is defined as an 8 by 8 pixel group.

[0042] A change detection algorithm is applied to determine the change in each corresponding region between the reference 64 and target 66 image.

[0043] In one embodiment, the image change detection algorithm is a normalized cross correlation algorithm, and is performed according the following formula (1)

[0044]

$$NCC(I_1, I_2) = \frac{\sum_i ((a_i - \bar{a})(b_i - \bar{b}))}{\sqrt{\sum_i (a_i - \bar{a})^2 \sum_i (b_i - \bar{b})^2}}$$

[0045]

[0046] where I_1 is a region in the reference image 64; I_2 is the corresponding region in the target image 66, a_i is the image pixel intensity value for location i in I_1 ; b_i is the

image pixel intensity value for location i in I_2 ; $\bar{a}$ is the average image intensity value for I_1 , and $\bar{b}$ is the average image intensity value for I_2 .

[0047] A threshold of NCC is pre-set for identifying the change. When the calculated value of NCC in any region is below the threshold, it signals that a change is detected within the region; and the process 100 proceeds to the next sub step 340. Otherwise, the process 100 will skip the remaining steps in the current process cycle, and proceed to step 200 of the next cycle to analyze the next target image 66 with respect to the same reference image 64.

[0048] In one embodiment, the pre-set threshold is 0.75.

[0049] In one embodiment, the entire image data of the acquired images 62 is used for change detection 320. In another embodiment, for fast operation, at least one command region is pre-determined in relation to the projected image 42, upon which the interaction of the laser spot is programmed to initiate a corresponding control action. Hence, only the image data corresponding to the pre-determined command region is extracted for change detection.

[0050] In one embodiment, the pre-determined command region is located within the view of the projected image 42. In another embodiment, the pre-determined command region is located in the boundary region of the projected image.

[0051] Still referring to FIG. 3, the step 340 is to identify the laser spot by determining a dominant color ratio in the region where a change is detected in step 320. For computer display and image scanning, RGB color model are widely used, in which three primary colors red (R), green (G) and blue (B) are combined in various ways to reproduce a broad array of colors. A color image pixel for each location of the image is represented as values for red, green, and blue. The dominant color ratio for each location in the region of change is calculated with respect to the color of the laser spot. The locations the calculated dominant color ratio of which exceeds a pre-set threshold, constitutes a sub region where the dominant color is the color of the laser spot.

[0052] In other embodiment, the dominant color ratio is calculated according to following formula (2):

[0053]
$$\text{Dominant color ratio} = L_i / (R_i + G_i + B_i)$$

[0054] wherein R_i is the value for the red component of the color image pixel in location i , G_i is the value for the green component of the color image pixel in location i , B_i

is the value for the blue component of the color image pixel in location i , and L_i is the value for the color component constituting the color of the laser spot in location i . For example, when the laser spot 52 is in red, L_i equals to R_i .

[0055] The pre-determined threshold is 0.6.

[0056] In another embodiment, for more accurate computation, the dominant color ratio is calculated according to the following equation (3):

[0057] *Dominant color ratio* $= L_i / \text{SQRT}(R_i * R_i + B_i * B_i + G_i * G_i)$

[0058] wherein R_i is the value for the red component of the color image pixel in location i , G_i is the value for the green component of the color image pixel in location i , B_i is the value for the blue component of the color image pixel in location i , and L_i is the value for the color component constituting the color of the laser spot in location i .

[0059] The pre-determined threshold is 0.85.

[0060] It is important to ensure that the laser spot can be efficiently identified according to dominant color ratio calculation, regardless of the color scheme of the projected image. To enhance detection sensitivity, in one embodiment, a virtual button with contrast color to the laser beam is created by a computer executable program and located on the pre-determined command region of the image. When the laser beam is in red, for example, the virtual button is pre-set in blue or green.

[0061] In another embodiment, the color with respect to which the dominant ratio is calculated, is varied by the system operator 10 during the display. For example, when the projected image is predominantly green, red laser beam is chosen for interactive display control, and the calculation of the dominant color ratio is with respect to the red color component. Likewise, when the projected image is predominantly red, the green laser beam is chosen, and the calculation of the dominant color ratio is changed so as to be with respect to the green color component..

[0062] In yet another embodiment, the dominant color ratios with respect to two distinct color components can be calculated simultaneously. For example, the laser pointer 5 is configured to generate a red laser beam and a green laser beam in parallel. The dominant color ratio for the red component is calculated in step 340, as well as the one for the green component. The process proceeds to the step 360, as long as one of the calculated ratios exceeds the pre-determined threshold.

[0063] Now referring to FIG. 4, there is provided an illustration the step 360. The step 360 is to verify the existence of the laser spot by determining the aspect ratio of the sub region identified in step 340. A bounding rectangle 67 is defined for enclosing the sub region in the target image 66. The aspect ratio of the identified sub region is calculated as the width divided by the height of the bounding rectangle. When the calculated aspect ratio falls within a pre-set range, it signals that the laser spot 52 is detected and verified.

[0064] In one embodiment, the pre-set range is from 0.8 to 1.2.

[0065] When a laser spot 52 is detected in the target image 66_n, during the subsequent process circle with respect to the target image 66_{n+1}, the change detection step 320 will be performed according to a nearest neighbor rule, in order to accelerate the process 100.

[0066] FIG. 5 provides a simplified illustration of the nearest neighbor rule. The acquired image is divided into 16 regions R_i (i=1,2,...16). In respect of the target image 66_n, a laser spot is detected in the region 7. According to the nearest neighbor rule, in respect of target image 66_{n+1}, the change detection algorithm will be performed in regions R₃, R₆, R₈, R₁₁ first, followed by R₂, R₄, R₁₀, R₁₂ and then progressively to outer sub-regions.

[0067] Now referring again to FIG. 2, to avoid undesirable display control in response to accidental laser pointing, the detected laser spot is required to be present in the same image region for a pre-determined duration in order to actuate the control action. In respect of a projected image 42, the reference image 64 is acquired at T₀. The target image 66_n is acquired at T_n, wherein a laser spot 52 is detected in the region K for the first time in respect of the reference image 64 according to the step 300. T_n is stored as the reference time for calculating the duration of the detected laser spot 52. The successive target images 66_{n+i} (i=1, 2, ...) are acquired at T_{n+i} respectively, wherein the laser spot 52 is consistently detected. In respect of each successive target images 66_{n+i}, the corresponding duration of the laser spot 52 is calculated in step 400 according to the following formula (4):

[0068]
$$\text{Duration}(i) = T_{n+i} - T_n$$

[0069] A threshold is pre-set for the duration. Only if the calculated duration exceeds the threshold, the process 100 proceeds to the step 500. Otherwise, the process 100 will skip the remaining steps in the current circle, and proceed to step 200 of the next circle to analyze the next target image 66 with respect to the same reference image 64.

[0070] In one embodiment, the pre-determined threshold of duration is 1 second.

[0071] Still referring to FIG. 2, the step 500 is to determine the coordinate of the detected laser spot and analyze in relation to the coordinate of any pre-determined command region. Once it is confirmed that the detected laser spot 52 is located within a pre-determined command region, the corresponding control action will be executed in step 600.

[0072] The above-described laser-pointer based interactive display system 1 and its operation process 100 can be used to control the display of computer generated electronic slide shows. Two example applications are described herein after.

[0073] FIG. 6 provides an illustration of applying the system 1 and process 100 to page up or down of the slides. The view of the acquired image 62 is larger than that of the corresponding projected image 42, including a left boundary region 62a and a right boundary region 62b. The left boundary region 62a is pre-determined as page-down command region, whilst the right boundary region 62b is pre-determined as page-up command region. When a laser spot 52 is detected in the left boundary region 62a for a pre-determined duration, the computer 2 displays the previous slide in response. Likewise, when a laser spot is detected in the right boundary region 62b for a pre-determined duration, the computer 2 displays the next slide. In this case, no virtual command button is required within the slide and the whole slide can be used for presentation material.

[0074] In another embodiment, the boundary region above the projected image is defined as page up command region, while the boundary region below the projected image is defined as page down command region.

[0075] FIG. 7 provides an illustration of applying the system 1 and process 100 to highlight the presentation information. Virtual button 22a, 22b are pre-programmed to be located at one corner of an electronic slide 22. The region covered by the virtual button 22a is defined as the command region for actuating the draw mode. When a laser spot 52 is detected within the virtual button 22a in the corresponding acquired image 42 and maintained for a pre-determined duration, the computer 2 actuates the pre-programmed draw mode in response, being ready to automatically track the subsequent movement of the laser spot 52, and modifies the current electronic slide 22 by drawing a line corresponding to the movement of the laser spot 52. To define a starting point for drawing, a laser spot shall be pointed at a location for a pre-determined time. To exit the draw mode,

the operator 10 needs to turn off the laser pointer 5 for a pre-determined time and then point at a virtual button 22b for a pre-determined time to deactivate.

[0076] In addition to a single operator interactive display control, the laser-pointer based interactive display system 1 and its operation process 100 can also be used for interactive display control by multiple operators. For example, the computer 2 is programmed to detect and differentiate laser spots of different colors and execute control actions accordingly. Hence, each operator can send interactive signals by using a laser pointer of a distinct control to control the display, e.g. superimposing lines on the projected image. And these interactive signals can be processed by the system simultaneously.

[0077] While the present invention has been described with reference to particular embodiments, it will be understood that the embodiments are illustrative and that the invention scope is not so limited. Alternative embodiments of the present invention will become apparent to those having ordinary skill in the art to which the present invention pertains. Such alternate embodiments are considered to be encompassed within the spirit and scope of the present invention. Accordingly, the scope of the present invention is described by the appended claims and is supported by the foregoing description.

Claims

1. A process executable by an interactive image display system for controlling image display, the interactive display system comprising:
 - a processor for generating an image and controlling the display thereof pursuant to an interactive signal;
 - a display surface;
 - a projector for projecting the processor-generated image onto the display surface;
 - a laser pointer for generating the interactive signal by superimposing a laser spot on the display surface that has the projected image displayed thereon; and
 - an image sensing device for continuously acquiring images of the display surface so as to detect the interactive signal;said process comprising the steps of:
 - detecting the laser spot superimposed on the display surface;
 - calculating the duration of the detected laser spot;
 - if the calculated duration exceeds a pre-set threshold, locating the position of the detected laser spot;
 - if the position of the detected laser spot is within a pre-determined command region, executing a corresponding control action.
2. The process of claim 1, wherein the view size of the acquired image by the image sensing device is the same as that of the corresponding projected image.
3. The process of claim 2, wherein the pre-determined command region is located within the projected image.
4. The process of claim 1, wherein the view size of the acquired image by the image sensing device is larger than that of the corresponding projected image.

5. The process of claim 4, wherein the pre-determined command region is located within the projected image.
6. The process of claim 4, wherein the pre-determined command region is located in a boundary region of the projected image.
7. The process of claim 1, wherein a virtual button is created by the processor in the electronic image in a region corresponding to the pre-determined command region.
8. The process of claim 7, wherein the virtual button is in a color contract to the color of the laser spot.
9. The process of claim 1, wherein when a laser spot is initially detected in target image n , and consistently detected in the subsequent target image $n+i$ ($i=1,2,\dots$), the duration of the detected laser spot is calculated according to the formula

$$\text{Duration}(i) = T_{n+i} - T_n,$$
 wherein T_n is the time when target image n is acquired by the image sensing device, and T_{n+i} is the time when target image $n+i$ is acquired.
10. The process of claim 1, wherein the corresponding control action is to display a previous/next processor-generated image.
11. The process of claim 1, wherein the corresponding control action is to enter information to the processor-generated image.